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Original Research Article

Public health risk analysis due to consuming Tilapia (*Oreochromis niloticus*) containing heavy metals in Bakan village, Lolayan district, Bolaang Mongondow regency

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ABSTRACT

Background: Gold mining activities, both legal or illegal, as well as public activities that live around Bakan River influenced the quality of water. These activities produce waste that contains heavy metals from gold production and derivative impacts of these activities. The waste then flows into the water and pollute the water and biota. People that use the water feel the impact like health problems. Tilapia (*Oreochromis niloticus*) is one of the fish in Bakan river that often consumed by people. Consuming fish that exposed to heavy metals in certain concentration is very dangerous for public health. A public health risk analysis is needed to estimate the magnitude of the impact. The research location is in the river on Bakan village, Lolayan district, Bolaang Mongondow regency. The aim of the study is to determine the levels of heavy metals Arsenic (As), Cadmium (Cd), Chromium (Cr), Mercury (Hg) and Lead (Pb) in Tilapia (Oreochromis niloticus)'s organs.
Methods: The type of this study is observational with Environmental Health Risk Assessment (EHRA) approach, where the number of respondents is 100 people.
Results: The results showed that the concentration of Cd (0.01<0.10), Cr (<0.1) and Pb (0.1<0.20) in fish is still below quality standard based on BPOM No. 23 of 2017. Health risk estimates obtained RQ>1 for metal As and Hg.
Conclusions: This study has proven that consuming Tilapia is not safe for health.

Keywords: Risk, Tilapia, Heavy, Metal

INTRODUCTION

Natural resources provide opportunities for business actors to exploit the natural wealth. Mining activities, both legal and illegal, give an impact on quality of water and aquatic biota. Not only decreasing the quality the affected water but also the people who consume the fish that live in the water's health. Heavy metals such as As, Cd, Hg and Pb that enter the water from mining activities will accumulated in fish body and this accumulative trait also applies in human body. Heavy metals accumulation in human body will have a non-carcinogenic and carcinogenic impact.[1] Non-essential heavy metals (micro elements) have no function in human body, and even very dangerous to cause poisoning (toxic) in humans. According to Widowati et al the effects of heavy metals depends on where the heavy metals bounded in the body and the amount of exposure dose. For example, mercury causes symptoms like tremors, shaking when standing, dizziness when standing, hands and feet pain, and central neurologic system disorders.[1] Research from Gani et al in Bakan village river obtained the following heavy metal levels: Cadmium (Cd) 0.0021 ppm, Lead (Pb) 0.011 ppm, Arsenic (As) 0.002 ppm, Chromium (Cr) 0.005 ppm, and Mercury (Hg) <0.0006x10-3 ppm. The result of this study is still below the threshold. However, low heavy metals in water do not mean that contaminants containing heavy metals do not have a negative impact on water.[2] When it over time, heavy metals will accumulate in sediments and eventually lead to accumulation in biota's body that live and forage in the water around sediments or the bottom of the water.[3] Heavy metals become dangerous because of the bioaccumulation process. Heavy metals can be accumulated through food chain, the higher the level in food chain occupied by an organism, the accumulation of heavy metals in its body also increases. The bioaccumulation in fish and marine products increase the risk of humans will experience the bioaccumulation process of heavy metals in their bodies.[4]

Heavy metals can cause negative effects in the life of living things such as interfering chemical reaction, inhibiting the absorption of essential nutrients. These heavy metals continuously accumulated in long term can cause neurological disorders, paralysis, and premature death as well as a decrease level of children intelligence.[5] Based on initial observation, people in Bakan village fish in the river for consumption. The type of fish thet commonly caught are Nilem (*Osteochilus vittatus*) and Tilapia (*Oreochromis niloticus*). Health complains that felt by people that work in illegal mines are itching and dizziness after they work. Data from Tanoyan public health center in 2021 found that skin diseases were included in 10 prominent diseases. One of the methods that can be used for analyze public health risk due to consuming fish containing As, Cd, Cr, and Pb in Tilapia is the environmental health risk analysis (EHRA) method.

EHRA can monitor non-carcinogenic effects called Risk Quotients (RQ). If the RQ is at least 1, the risk does not need to be controlled, but if the RQ is less than 1, the risk the risk does not need to be controlled but to be maintained so the RQ does not exceed from 1.6. Based on the existing background, it can be formmulated the problem in the research is how big is the risk of public health problems due to consuming tilapia (Oreochromis nolilicus) that contains As, Cd, Hg, and Pb in Bakan village river, Lolayan District, Bolaang Mongondow Regency. The aim of the study is to determine the levels of heavy metals Arsenic (As), Cadmium (Cd), Chromium (Cr), Mercury (Hg) and Lead (Pb) in Tilapia (*Oreochromis niloticus*)'s organs.

METHODS

Study design, location and duration

This study used a descriptive research design using the environmental health risk analysis (EHRA) method. This research was conducted in Bakan village river, Lolayan district, Bolaang Mongondow regency and was carried out in April 2022. The sampling method was determined by purpose sampling. The Sampling was carried out in three points that consisting in upstream (before the pollutant source), middle (pollutant source) and downstream of the river.

Table 1: Tools and materials for sampling and parameter test.

Parameter	Unit	Tools/ Methods	Measurement
Water			
As	mg/l	APHA-3120-B (2017)	Ex situ
Cd	mg/l	APHA-3120-B (2017)	Ex situ
Cr	mg/l	APHA-3120-B (2017)	Ex situ
Pb	mg/l	APHA-3120-B (2017)	Ex situ
Hg	mg/l	USEPA-245-1 (2005)	Ex situ
Fish			
As	mg/kg. wet	WI-(ID)-(EHS)-LA-069(ICP OES)	Ex situ
Cd	mg/kg. wet	WI-(ID)-(EHS)-LA-069(ICP OES)	Ex situ
Cr	mg/kg. wet	WI-(ID)-(EHS)-LA-069(ICP OES)	Ex situ
Pb	mg/kg. wet	WI-(ID)-(EHS)-LA-069(ICP OES)	Ex situ
Hg	mg/kg. wet	WI-(ID)-(EHS)-LA-069(ICP OES)	Ex situ
Sediment			
As	mg/kg. dry	WI-(ID)-(EHS)-LA-070(ICP-OES)	Ex situ
Cd	mg/kg. dry	WI-(ID)-(EHS)-LA-070(ICP-OES)	Ex situ
Cr	mg/kg. dry	WI-(ID)-(EHS)-LA-070(ICP-OES)	Ex situ
Pb	mg/kg.dry	WI-(ID)-(EHS)-LA-070(ICP-OES)	Ex situ
Hg	mg/kg.dry	WI-(ID)-(EHS)-LA-070(CV-AAS)	Ex situ

Preparation and sampling

This study involved 100 adults as respondents that live in Bakan and consuming Tilapia. Sampling of water and sediment was carried out using a composite method. Sampling of fish using fishing rods and sediment with Ekman grab tool. The fish meat was sliced through the whole fish along the spine starting from the back of the head to approach the tail (fillet). Fish meat, water, and sediment samples were refrigerated and transported for heavy metals content analysis in the laboratory.

Inclusion and exclusion criteria

Inclusion criteria for current study were; respondents are more than 5 years old and who were consuming tilapia from the Bakan river. Exclusion criterion for current study was respondants domiciled outside the research location.

Data analysis

Tools and materials for sampling and parameter test can be seen in (Table 1). Univariate analysis was used for the variable concentration of heavy metals in fish, frequency of exposure, duration of exposure, and body weight. Environmental health risk analysis (EHRA) is carried out through 4 stages, namely hazard identification, exposure analysis, dose-response analysis; hazard identification can be seen in (Table 2).

Table 2: Hazard identification.

Identification	Description
Risk agent	**As, Cd, Cr, Hg dan Pb**
Environment media	Air
Trait	Non-carcinogenic, carcinogenic
Acute effect	Shiver, fever, muscle ache, headache, skin infection
Chronic effects	Proteinuria, heart disorder, lung disorder, kidneys disorder neurological disorder, cardiovascular system disorder death

Dose-response analysis

Dose-response analysis was conducted to determine the dose that was exposed to the human body and did not cause any health effects. This dose is referred to a reference dose. Reference dose for non-carcinogenic effects declared as the Reference Dose (RfD). RfD values are different for each heavy metal and are obtained based on references (Table 3).[7]

Table 3: Reference dose of non-carcinogens.

Non-carcinogen	As	Cd	Cr	Pb	Hg
RfD/ (mg·kg^{-1}day^{-1})	3x10^{-4}	1x10^{-3}	3x10^{-3}	4x10^{-3}	1x10^{-4}

Exposure analysis

The next stage in health risk analysis is the exposure analysis. This stage includes forecasting the path of contaminants exposure in polluting media and potential risk of contaminating the population. Exposure analysis to people who consume Tilapia is carried out by calculating the intake rate of Tilapia and exposure frequency per day. The intake rate of Tilapia on people in Bakan village is obtained by calculating how much Tilapia is eaten by people per day. The exposure frequency is obtained by knowing the number of days in a year for people who consume Tilapia.

Risk characteristics

Risk characteristics are estimates of an adverse risk that can occur in humans resulting from exposure to heavy metals. The estimation can be done with risk estimation, the quantification of the probability of risk occurrence based on hazard identification, effect analysis and exposure analysis. Risk level or RQ (Risk Quotients) is the ratio of intake to reference dose. The RQ value indicate the risk level for non-carcinogenic effects. Health risk are stated to exist and need to be controlled if RQ>1.[6]

The equation that was used to calculate the RQ is:

$$RQ = \frac{Ink}{RfD}$$

Where: Ink = non-carcinogenic intake (mg/kg weight/day), RfD = reference dose (mg/kg weight/day).The Intake amount is calculated using the equation:

$$I = \frac{C \text{ x } R \text{ x } fE \text{ x } Dt}{Wb \text{ x } t \text{ avg}}$$

Where: I=Intake (mg/kg/day), C=risk agent concentration (mg/ l), R=intake or consumption rate (g/day), fE=exposure frequency (day/year), Dt=exposure duration (30 years for residential default), Wb=body weight (kg). tavg=average time period (70 years x 365 day/year for carcinogens, Dt x 365 day/year for non-carcinogens).

Risk management

Risk management will be carried out if the risk quotients (RQ)> 1.[6] The method is to reduce the rate of intake/consumption and frequency of exposure mathematically so that it becomes

$$R= \frac{RfD \text{ x } Wb \text{ x } tavg}{C \ x \ fE \ x \ Dt} \text{ and } Fe = \frac{RfD \text{ x } Wb \text{ x } tavg}{C \text{ x } R \text{ x } Dt}$$

RESULTS

Based on (Table 4), it is depicted that from 100 respondents there were 17 respondents who suffered from itching on the hands, feet, body, waist, stomach. There were 22 respondents who experienced digestive disorders with a period of 1-14 days. There were 53 respondents who experienced gastric disorders and 48 respondents who experienced joint muscle pain. Based on the results presented in (Table 5), the content of heavy metals in water is still below the quality standard set by PP RI Number 22 of 2021.[8] The content of As, Cd, Hg and Pb in sediments in the Bakan river has exceeded the quality standard set by Canadian sediment quality for the protection of aquatic life.[9] The content of As and Hg in fish in the Bakan river has exceeded the quality standard set by the food and drug supervisory agency (BPOM) No. 23 of 2017 while the levels of Cd, Cr and Pb are still below the threshold.[10] The average duration of exposure to tilapia was 35.29 years with the lowest duration of exposure being 2 years and the highest being 82 years as depicted in (Table 6).

Table 4: Characteristics of respondents based on disease symptoms distribution.

Skin disease symptoms last 10 years experienced by respondents			
Type of skin problems	**Yes**	**No**	**Location on body**
Itchy	17	83	Hands, feet, body , waist, stomach
Reddish	16	84	Hands, feet, body , waist, stomach , thigh , neck
Nodules without liquid	6	94	Hands, thigh, brisket, stomach
Nodules with liquid	5	95	Hands, thigh, feet, body
Bumps	12	88	Hands, shoulder, feet, stomach, brisket, body
watery wound	2	98	Feet
Fester	4	96	Feet, hands
Lumps	2	98	Feet
Scaly skin	8	92	Hands, feet, body,
Indigestion experience from respondents last two weeks			
Type of indigestions	**Yes**	**No**	**Duration**
Oral cavity	17	83	1-30 days
Metallic taste in mouth	16	84	1-10 days
Neck wound/hard to swallow	22	78	1-14 days
nausea/vomitting	17	83	1-14 days
Heartburn/stomach ache	15	85	1-3 days
Diarrhea/diarrhoea	7	93	1-4 days
Neurological disorders experience from respondents last 10 years			
Type of neurological disorders	**Yes**	**No**	**Duration**
Tremor/shaking in limbs	23	77	1-14 days
Stomach disorder	53	47	1-90 days
Anemia	26	74	1-30 days
Liver disorder	2	98	3 month-10 years
Muscle or joint pain	48	52	1-30 days
Lungs	3	97	1 days-6 month

Table 5: Concentration of As, Cd, Cr, Hg, and lead in water, sediment and Tilapia (oreochromis niloticus) during research.

Parameter	Water (mg/l)	Water quality standard[1]	Sediment (mg/kg dry)	Sediment quality standard[2]	Tilapia (mg/kg wet)	Fish quality standard[3]
As	0.009	0.05	21	7.24	0.9	0.25
Cd	0.0001	0.01	2.82	0.7	<0.01	0.10
Cr	<0.001	0.05	16.6	52.3	<0.1	-
Hg	<0.00005	0.002	3.26	0.13	0.081	0.06
Pb	<0.001	0.03	50.6	30.2	<0.1	0.20

The frequency of exposure in this study showed that the average frequency of exposure to milkfish by housewives in the Tambak Lorok area was 75.22 days/year with the lowest frequency of exposure being 4 days/year and the highest 144 days/year. The average intake rate of Tilapia is 122.20 g/day with the lowest intake rate of 40 g/day and the highest 210 g/day. The average body weight of respondents who consumed Tilapia was 60.82 kg with the lowest weight being 30 kg and the highest being 96 kg. There were 48 respondents (48%) who had RQ>1 for heavy metal As in fish. For the risk of consuming Tilapia containing Hg, 10 respondents (10%) had RQ>1. From these results it was concluded that consuming Tilapia in the Bakan River had health risks or was unsafe for consumption. The risk model is used for a period of 30 years, the effects of the toxicity of Arsenic and Mercury metals will be felt in the next 30 years. People weighing 30 kg have a safe limit for consuming tilapia which contains 0.07 g/day of arsenic and 0.26 g/day of mercury as depicted in (Table 7).

DISCUSSION

The development of rapid and concomitant in low and middle-income countries raises the problem of cardiovascular disease (CVD) and diabetes due to heavy metal exposure.[11] Large amounts of exposure of As for 30 minutes to 2 hours can cause symptoms of nausea, vomiting, burning throat, stomach ache, diarrhea, dry mouth and metallic taste, difficulty swallowing and even death.

Table 6: Descriptive distribution on intake rate variable (R), exposure frequency (fE), exposure duration (Dt), body weight, As intake, Hg intake, As RQ and Hg RQ in people around Bakan Bolaang Mongondow river.

Variable	Mean	Min	95% CI (lower and upper bound)	SD	Kolmogorov-Smirnov	
	Median	Max			Statistic	P value
Exposure duration (year)	35.29	2	31.58	18.695	0.092	0.037
	31.50	85	39.00			
Exposure frequency (day/year)	75.22	4	66.52	43.829	0.243	0.000
	48.00	144	83.92			
Intake rate (m^3/day)	122.20	40	114.18	40.410	0.118	0.002
	120.00	210	130.22			
Respondents Weight (Kg)	60.82	30	58.40	12.182	0.081	0.099
	60.00	96	63.24			
As Intake	0.00048302	0.000010	0.00038322	0.000502954	0.173	0.000
	0.00030575	0.002371	0.00058282			
Hg Intake	0.00004347	0.000001	0.00003449	0.000045266	0.173	0.000
	0.00002752	0.000213	0.00005245			
As RQ accumulation for 30 years exposure	1.61	0.03	1.27	1.67	0.173	0.000
	1.01	7.90	1.94			
HQ RQ accumulation for 30 years exposure	0.36	0.01	0.31	0.27	0.115	0.002

Table 7: Consumption intake safe Tilapia consumption to people in area of Bakan river.

Body weight (Kg)	Consumption intake (As) (gram/day)	Consumption intake (Hg) (gram/day)
30	0.07	0.26
40	0.09	0.35
50	0.12	0.44
60	0.14	0.53
70	0.16	0.62
80	0.19	0.71
90	0.21	0.80

Symptoms of acute Cd poisoning after 4-10 hours are the existence of pain and heat on chest, flu-like symptoms exist, tremble and cold, diarrhea, migrants, difficult to learn something, growth disorders and death. Chronic symptoms are damage to the physiological system, causing kidney damage and others. Cr metal is a chemical that is persistent, bioaccumulate, and toxic. Cr toxicity is carcinogenic and can cause lung cancer, respiratory and upper respiratory tract disorders. The conversion of Cr (VI) to Cr (III) by the body can reduce the toxicity of Cr. Pb metals that can inhibit enzyme activity in the body so that it affects the formation of hemoglobin (Hb). Lead acute toxicity causes symptoms of gastrointestinal disorders (abdominal cramps, vomiting, nausea), neurological disorders (headaches, frequent fainting and coma), and kidneys function disorder. Chronic Lead exposure can cause fatigue, irritability, gastrointestinal disorders, libido loss, male infertility, menstrual disorders, depression, headaches, difficult to concentrate, impaired memory and insomnia. Contamination of Hg in humans can occur through food, drink, inhalation and skin contact or living around industrial areas that use Hg. Chronic symptoms in the form of digestive and nervous system disorders in the form of tremors, Parkinson’s, eye lens disorder and mild anemia.[1] The heavy metals in water caused by mining and agricultural activities. Besides, heavy metals are naturally existing in waters due to weathering rocks. The main factors in the cause of heavy metal pollution are both naturally and synthetically happen. Sediments that consist of heavy metals have through adsorption, precipitation, diffusion, chemical reaction, biological activities and others.[12] The sediment that consists of As, Cd, Hg, and Pb in Bakan village river has exceeded the quality standard set by Canadian sediment quality for the protection of aquatic life. Sediments receive heavy metals through chemical and physical rock processes, soil percolation and physiological processes of various plants.[13] The content of heavy metals in water is lower than in sediment. But it does not mean that the water is safe for the biota. If pollution continuously occurs, it will cause accumulation in the body of biota that live and forage in the water around sediment or the bottom of the water, which will be dangerous for humans who consume these biotas in turn.[3] Heavy metals like Al, Mn, Ni, Pb and Cu in water surface and sediments in Brahmaputra Bangladesh river are caused by industrial activities such as textile crafts, spinning mills, cotton, burlap factories and others.[14] In general, metals in minerals and rocks are harmless but more toxic when dissolved in water.[15] Water pollution due to disposal of residual mining waste contains mercury that quite high when compared to air pollution of mercury. Alkylmercury is a mercury compound that widely used in agriculture (for hatchery process), it is the main source of mercury pollution in food chain.[16] Heavy metals known as the causes of bad effects on human health through the food chain. The human health risks were evaluated from contaminated fish with heavy metals consumption from Bakan River. Research conducted by Simbolon et al obtained the concentration of Pb in green mussels (*Perna viridis*) has exceeded the threshold and the RQ value >1.

Consuming green mussels in cilincing waters is no longer safe.[17] Makmur et al found that using a maximum portion size of the cilincing community of 650.70 g, the value of witnesstotoxin exposure is 1.88 g/kg b.b. the value is still below the exposure value agreed by the EFSA panel which is 5.3 g/kg. Based on the RQ value for the highest exposure, which is around 0.35, it means that the RQ value <1 so it is still safe.[18] Kortei's et al found that consuming *Oreochromis noliticus* and *Clarias anguillaris* fish from the Ankobrah river is still safe for children and adults because the Hazard quotion value is still below 1 (HQ<1).[19] The research of Simbolon et al depicted that analysis of health risks for people who have direct activities (bathing, swimming, fishing) shows an RQ value >1, meaning that coastal communities are at risk of being adversely affected by exposure to heavy metals Pb, Cd and Zn. Similarly, the results of the risk analysis through the consumption of shellfish biota, with RQ values >1 and ECR >10-4. This shows that shellfish (*Placuna placenta*) is not suitable for consumption by the public, because the content of Pd, Cd, and Zn poses a risk to health for consumption.[20] Kawser et al stated that there are potential risks to human health in consuming fish from the Buriganga river which contains Cd, As, Pb, Cr, Ni, Zn, Se, Cu, Mo, Mn, Sb, Ba, V and Ag metals.[21] Research by Ezemonye et al revealed the target hazard quotient (THQ) for heavy metals in water (oral exposure) and fish consumption is above the threshold value of 1 which indicates a potential health risk.[22]

The content of As and Hg in fish on Bakan river has exceeded the quality standard that set by agent of food and drug supervisory No. 23 in 2017 while the levels of Cd, Cr, and Pb are still below the threshold. Heavy metals accumulation in fish occurs through the food chain. Heavy metals have natural affinity to keep locked in the sediment compartment because of the tendency of active precipitation. Then int wil absorbed by biota and aquatic plants.[23] The assessment of heavy metals is very important because it is a potential ecology indicator especially for pollution studies. Fish can show the impact of water pollution by metals on ecosystem. Disease etiology in fish and human is related to water pollution and metals accumulation in organisms.[24] The content of heavy metals in fish describe the past exposure condition through the water and/or for and it could indicate the animal situation before the toxicity affects ecological balance of the population in aquatic environment.[25] Consuming fish meat that contaminated by heavy metals like Cd will settled in liver and kidneys and will cause human health problems.[24] Risk management is carried out through 3 approaches, namely a technological approach, a socio-economic approach, and an institutional approach. Management can be done by reducing the rate of fish consumption to below the safe limit. Law enforcement for entrepreneurs who violate the rules of waste management is absolutely necessary so that cases of pollution in the Bakan river can be reduced. Prevention and control in industries that produce heavy metal waste and control of water pollution that causes high concentrations of heavy metals. The participation of the community around the Bakan river in preserving the coastal environment is very much needed in sustainable environmental management.[20]

Limitations

Limitation of the study is the people who consume tilapia in the Bakan river vary in the amount of fish consumed per day, besides that the size of the fish consumed is sometimes different from the standard set.

CONCLUSION

The content of heavy metals in water is still below the quality standard, while the content of heavy metals (As, Cd, Hg and Pb) in the sediment has exceeded the quality standard, and the content of heavy metals (As and Hg) in fish has also exceeded the quality standard. Consuming Tilapia in the Bakan River has health risks or is unsafe for consumption. The risk model is used for a period of 30 years, the effects of the toxicity of Arsenic and Mercury metals will be felt in the next 30 years

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